

2.1: b - RNA: Structure, Types

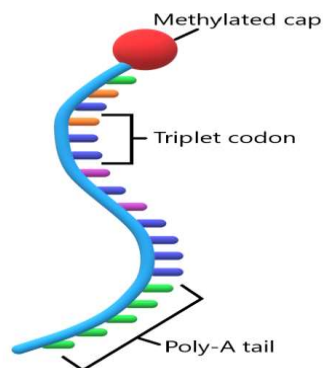
Ribonucleic acid (RNA) is a polymeric molecule essential in various biological roles in coding, decoding, regulation and expression of genes.

- ❖ Along with lipids, proteins, and carbohydrates, nucleic acids constitute one of the four major macromolecules essential for all known forms of life.
- ❖ Like DNA, RNA is assembled as a chain of nucleotides, but unlike DNA, RNA is found in nature as a single strand folded onto itself, rather than a paired double strand.
- ❖ Cellular organisms use messenger RNA (*mRNA*) to convey genetic information that directs synthesis of specific proteins. Many viruses encode their genetic information using an RNA genome.
- ❖ Some RNA molecules play an active role within cells by catalyzing biological reactions, controlling gene expression or sensing and communicating responses to cellular signals.
- ❖ One of these active processes is protein synthesis, a universal function in which RNA molecules direct the synthesis of proteins on ribosomes.
- ❖ This process uses transfer RNA (*tRNA*) molecules to deliver amino acids to the ribosome, where ribosomal RNA (*rRNA*) then links amino acids together to form coded proteins.
- ❖ Mainly three types of RNA present in all living organisms. These three types of RNA are:
 - mRNA (messenger RNA)
 - rRNA (ribosomal RNA)
 - tRNA (transfer RNA)

I) mRNA (messenger RNA)

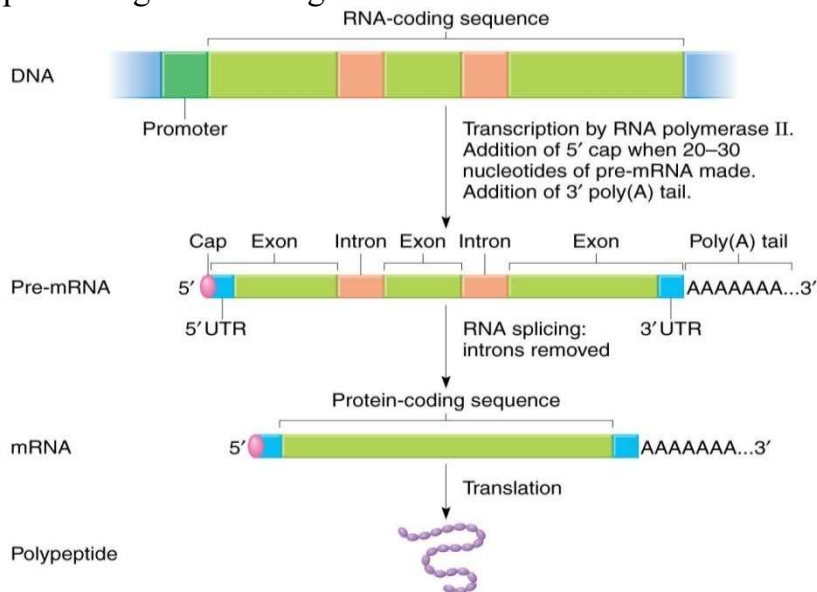
- ❖ The mRNA molecule is synthesized on DNA molecule by the process of transcription.
- ❖ mRNA discovered by Brenner, Jacob and Meselson in 1961.
- ❖ It constitutes about 3-5 % of total cellular RNA.
- ❖ For the synthesis of mRNA, one strand of the DNA acts as template.
- ❖ The synthesis of mRNA from DNA is catalysed by an enzyme called RNA polymerase.
- ❖ Synthesis of mRNA begins at 5' end and proceeds to 3' end and stops at terminal side.
- ❖ RNA polymerase attaches to DNA at the initiator sites.
- ❖ There is complementary base pairing of free bases of one of the DNA strand and ribonucleotides, resulting in the formation of mRNA strands.
- ❖ The lifespan of mRNA is 1-2 minutes in prokaryotes but in eukaryotes are many hours to even days.

- ❖ There are two types of mRNA namely monocistronic mRNA and polycistronic mRNA
- ❖ **Monocistronic mRNA:** When one gene i.e. cistron codes for a Single mRNA strands and which codes for one molecule of protein is called monocistronic mRNA
- ❖ **Polycistronic mRNA:** Several adjacent gene i.e. cistron transcribes the mRNA molecule which codes for more than one protein molecule is called polycistronic mRNA.



Hn-RNA (Pre mRNA)

- ❖ In eukaryotic cells the mRNA that comes to cytoplasm is the product of processing of a heterogenous nuclear RNA or Hn-RNA.



Structure of Hn-RNA

Structurally the Hn-RNA molecule is differentiated in the following regions.

CAP

- ❖ It is a blocked methylated structure is found at the 5' end of the mRNA.
- ❖ The rate of protein synthesis is depends upon the presence the CAP.
- ❖ Without CAP mRNA shows less chance of binding to the ribosomes.

Non-coding Region [Introns]

- ❖ It is present after the CAP and consist the 10 to 100 nucleotides.
- ❖ There are multiple non-coding region present on the Hn-RNA molecule.
- ❖ It is rich in 'A' and 'U' bases and does not code for any amino acids.
- ❖ It cleaved by the RNA splicing process and forms the mRNA

The Initiation Codon

- ❖ AUG acts as initiation codon, which helps to start protein synthesis.

Coding Region (Exons)

- ❖ It is a coding region and consisting about 1500 nucleotide and code for amino acids.
- ❖ Coding region called as exons.

Termination Codon

- ❖ Out of the all codons the 3 codons do not specify amino acids and hence the polypeptide chain terminates, these are nonsense codons are- UAA UAG and UGA.

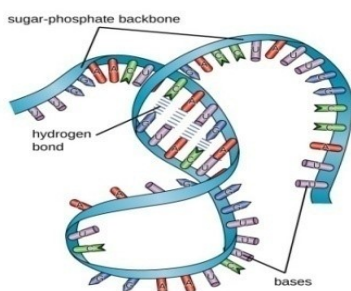
Poly A sequence

- ❖ It is the last region present at the 3' end and consist 20 do 200 nucleotide pairs of adenine residues.
- ❖ Therefore it is called polyadenylate or poly 'A' sequence.
- ❖ This sequence is added in nucleus before the mRNA reaches to cytoplasm.

Functions

- ❖ Specifically, messenger RNA (mRNA) carries the protein blueprint from a cell's DNA to its ribosomes, which are the machines that drive protein synthesis.

II) rRNA (ribosomal RNA)



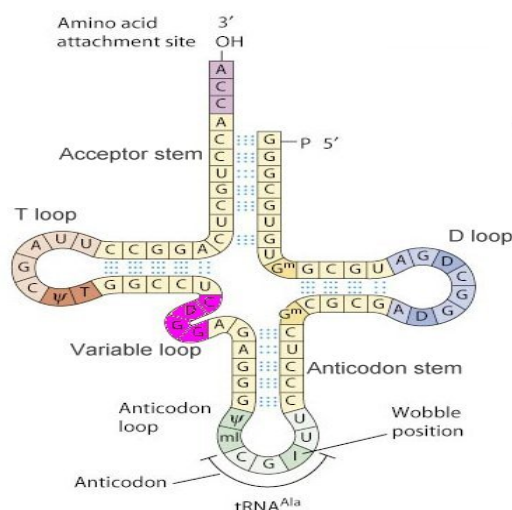
- ❖ rRNA discovered by George E. Palade in 1955.
- ❖ It is a single-stranded RNA molecule found in cells that forms the part of the protein synthesizing organelle, ribosome.
- ❖ Eukaryotic ribosomes contain four different rRNA molecules: 18S, 5.8S, 28S and 5S rRNA. Three of the rRNA molecules are synthesized in the nucleolus, and one is synthesized elsewhere.

- ❖ The synthesized rRNA can be varying in size, commonly distinguished as small and large.
- ❖ It constitutes about 80% of the total cellular RNA.
- ❖ rRNA consist of single polynucleotide strand which is twisted upon itself in some regions and forms helical structure with complementary base pairs and joined by hydrogen bond.
- ❖ In the unfolded region the base remains unpaired.
- ❖ Because of the pairing of bases at folded region and unpairing at unfolded region the rRNA does not show purine and pyrimidine equality.
- ❖ The rRNA molecule may be a compact coiled and an folded strand unfolds upon heating and refolds upon cooling.
- ❖ These newly synthesized rRNAs combine with ribosomal proteins and form smaller and larger subunits of ribosomes respectively.
- ❖ These rRNAs are vital in recognizing conserved regions of incoming mRNAs and tRNA thus facilitating their binding and carrying out protein synthesis.
- ❖ Additionally, rRNA also has enzymatic activity peptidyl transferase and catalyzes to the formation of the peptide bond in between two aligned proteins and amino acids during protein synthesis.

Functions

- ❖ rRNA ensures the proper alignment of the mRNA and the ribosomes during protein synthesis and catalyses the formation of the peptide bonds between two aligned amino acids during protein synthesis.

III) tRNA (transfer RNA)



- ❖ It is a type of RNA molecule that helps to decode information present in mRNA sequences into specific proteins.
- ❖ It constitutes about 10-20 % of the total cellular RNA.
- ❖ In 1958 Hoagland and Zemecnik discover the t RNA.

- ❖ It is encoded by DNA in the cell nucleus and transcribed with the help of RNA polymerase III.
- ❖ The structure of tRNA folds upon itself and creates an intra complementary base pairing which gives rise to hydrogen-bonded stems and associated loops that contains nucleotides with modified bases.
- ❖ The structure in two-dimensional resembles a cloverleaf having three loops and an open end are usually 75-90 ribonucleotides in length.
- ❖ Each of these loops consisting of arms has a distinct name and function.
- ❖ The three-loop consisting arms are namely: DHU or D arm, which has recognition site for specific enzyme amino-acyl tRNA synthetase; T arm that consists of ribosome recognition site and Anticodon arm that recognizes and bind to mRNA present in the ribosome.
- ❖ The open end with no loop is the site for attachment of amino acid, via 3' OH bonding with COOH- group of the amino acid.
- ❖ In general, tRNA reads the code on the mRNA sequence in Ribosome and translates specific amino acid; it does along the length of the mRNA and gives out a polypeptide chain of amino acids (proteins) in association with other important enzymes like aminoacyl tRNA synthetase and peptidyl transferase.
- ❖ **Acceptor arm** - The acceptor stem consist seven base pairs and four unpaired nucleotide units. The four unpaired nucleotides include 3' terminal CCA sequence and fourth nucleotide may be A or G. The amino acid molecule attached to the 3' terminal end the CCA sequence, which is known as amino acid binding site.
- ❖ **DHU arm (Di-hydro-uridine loop)** - It is second arm of tRNA consist 15 to 18 nucleotides with 3 to 4 base pairs in the stem and 7 to 11 unpaired nucleotide in the loop.
- ❖ **Anticodon arm** - It is third arm consist of an anticodon stem of 5 base pairs and loop called the anticodon loop, this loop containing seven unpaired nucleotides of which middle three forms the anticodon. The sequence of anticodon is complementary to codons of mRNA. It is the most specific region of tRNA.
- ❖ **The lump** - The fourth arm is also called variable arm or the lump. It is of two types, one containing 4 to 5 bases but no stem and second with 13 to 21 residues with stem and loop.
- ❖ **T ψ C arm (Pseudouridine ψ)** - It consists of 5 base paired stem and loop of seven nucleotides. The outermost pair of five base pair is C $\equiv$ G. It is the ribosomal recognition site

Functions of tRNA

- ❖ tRNA carries a specific amino acid from the cytoplasm to the ribosomes.
- ❖ It picks up the specific activated amino acid for protein synthesis.
- ❖ The tRNA transfers the amino acids to the growing polypeptide chain in the ribosomes, which has three binding sites for tRNA, namely A, P and E which corresponds to aminoacyl, peptidyl and exit respectively.